US009416782B2

(12) **United States Patent**
Kan et al.

(10) **Patent No.: US 9,416,782 B2**
(45) **Date of Patent: *Aug. 16, 2016**

(54) **OIL PUMP**

(71) Applicant: **YAMADA MANUFACTURING CO., LTD**, Kiryu-shi (JP)

(72) Inventors: **Yasuhiko Kan**, Kiryu (JP); **Hiroyuki Taguchi**, Kiryu (JP); **Sentaro Nishioka**, Kiryu (JP)

(73) Assignee: **YAMADA MANUFACTURING CO., LTD.**, Kiryu-shj, Gunma (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 57 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/333,157**

(22) Filed: **Jul. 16, 2014**

(65) **Prior Publication Data**

US 2015/0037194 A1 Feb. 5, 2015

(30) **Foreign Application Priority Data**

Jul. 30, 2013 (JP) 2013-157311
Jun. 12, 2014 (JP) 2014-121537

(51) **Int. Cl.**

F04C 18/08	(2006.01)
F01C 21/18	(2006.01)
F04C 15/06	(2006.01)
F04C 29/12	(2006.01)
F04C 14/24	(2006.01)
F04C 2/08	(2006.01)
F04C 2/10	(2006.01)
F04C 14/26	(2006.01)

(52) **U.S. Cl.**
CPC ***F04C 14/24*** (2013.01); ***F04C 2/084*** (2013.01); ***F04C 2/102*** (2013.01); ***F04C 14/26*** (2013.01); *F04C 2210/206* (2013.01)

(58) **Field of Classification Search**
CPC F04C 14/24; F04C 2/084; F04C 2/102
USPC 418/206.8, 171, 15, 180, 75, 76; 417/440, 540
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,588,011 B2 * 9/2009 Ono .... F04C 2/102 123/196 R
2015/0037193 A1 * 2/2015 Inoue F04C 2/102 418/61.3

FOREIGN PATENT DOCUMENTS

JP 63-246482 A 10/1988
JP 07145785 A * 6/1995 .... F04C 2/10

* cited by examiner

Primary Examiner — Kenneth Bomberg
Assistant Examiner — Deming Wan
(74) *Attorney, Agent, or Firm* — McGinn IP Law Group PLLC

(57) **ABSTRACT**

An oil pump has a pump body, an outer rotor, and an inner rotor. The pump body includes a rotor chamber, an inlet port and an outlet port formed in the rotor chamber, an inlet passage communicating with the inlet port, an outlet passage communicating with the outlet port, a relief valve, a relief chamber formed on a discharge side of the relief valve, and an oil return passage formed from the relief chamber to the inlet passage. The outer rotor is supported by the inner circumferential support wall of the rotor chamber. The oil return passage is formed in the inner circumferential support wall as a groove-like recess and opens along an outer circumferential surface of the outer rotor.

11 Claims, 7 Drawing Sheets

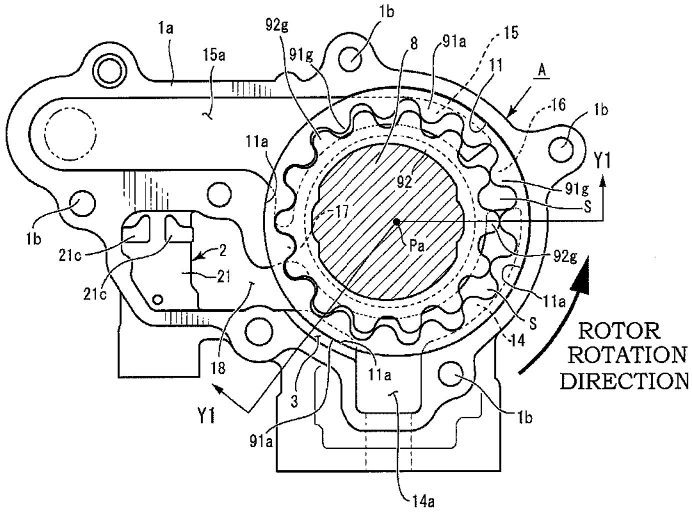


Fig. 1A

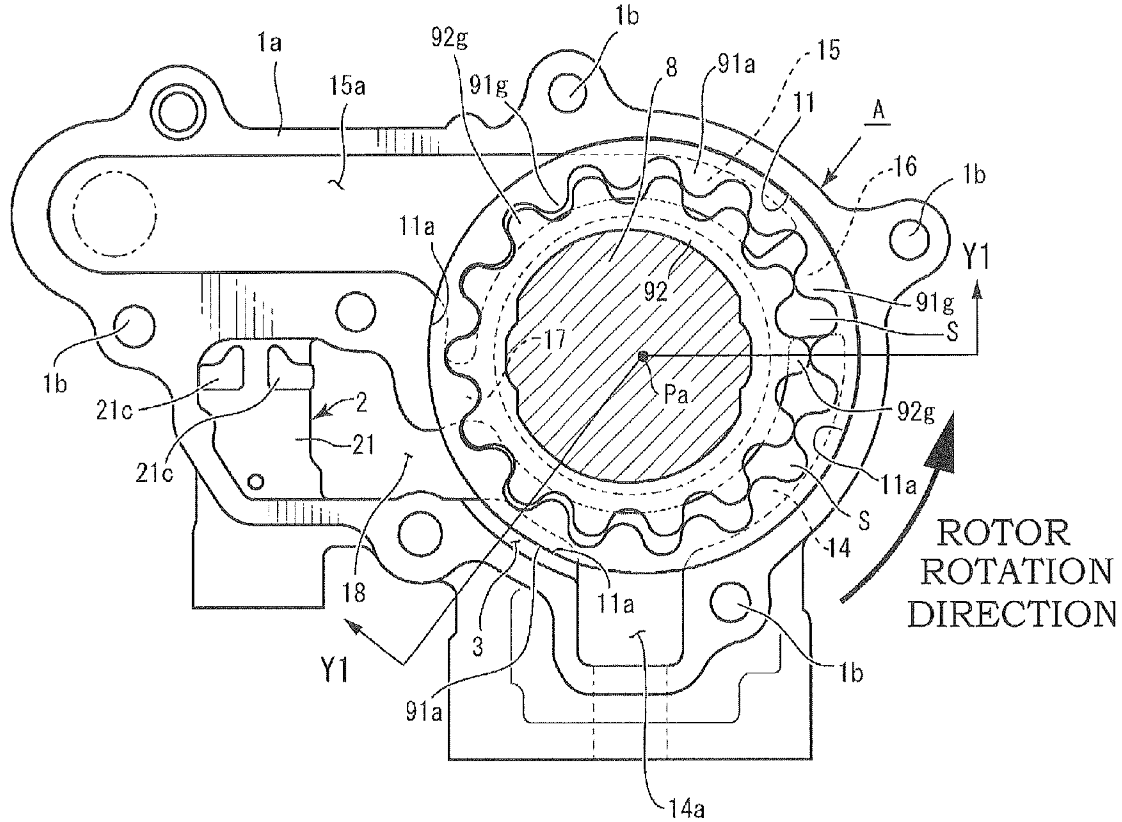


Fig. 1B

ENLARGED VIEW OF SECTION Y1-Y1
AS SEEN IN DIRECTION OF ARROWS

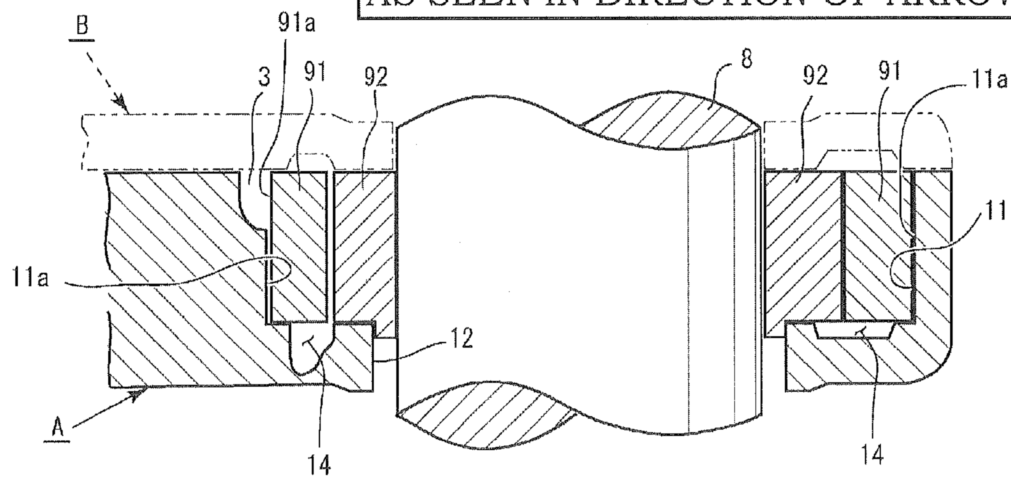


Fig. 2A

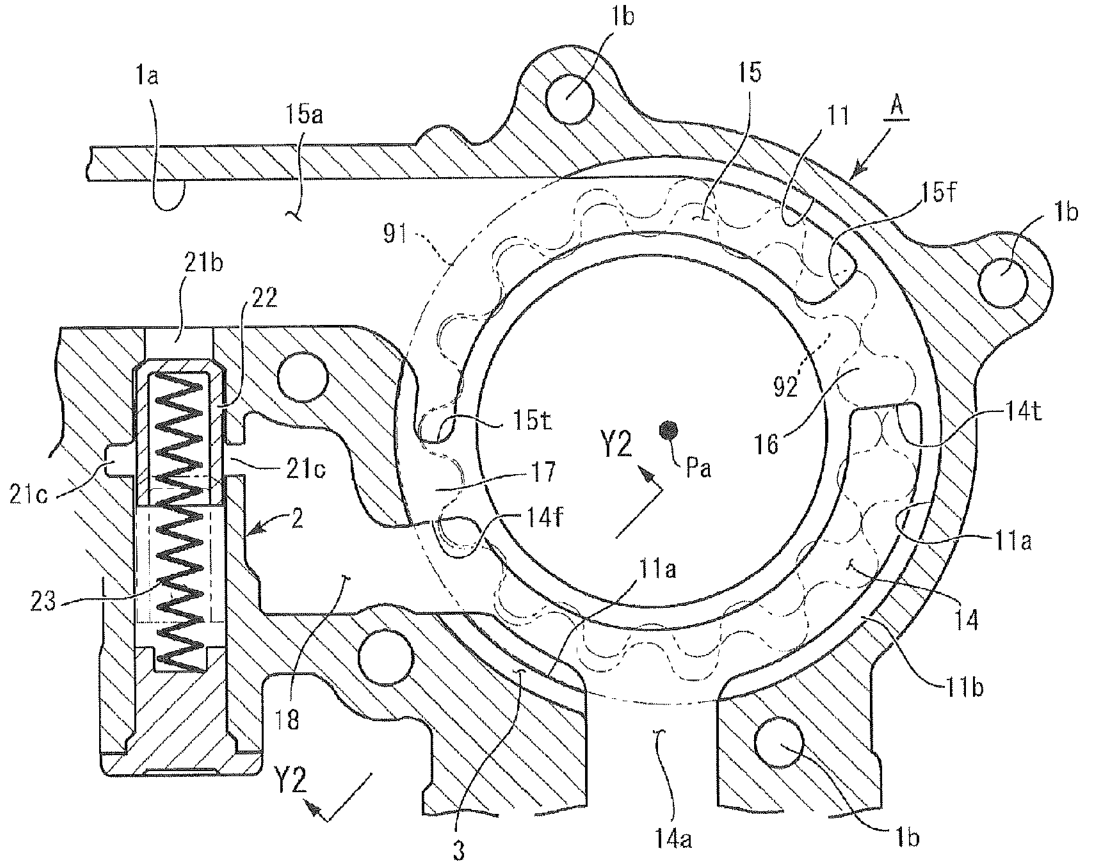
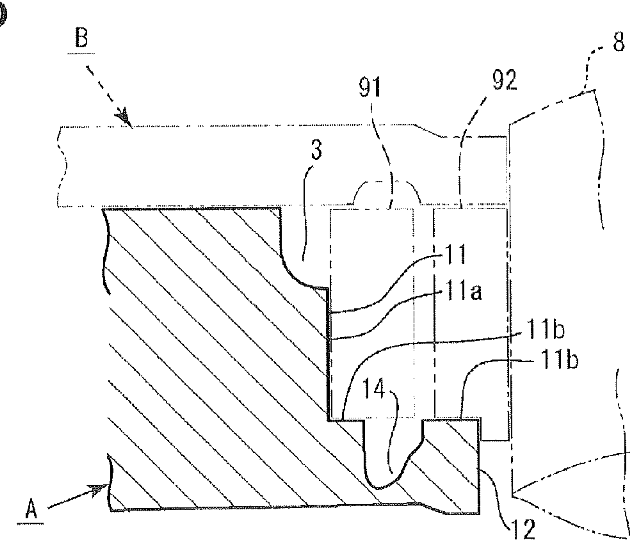


Fig. 2B



SECTION Y2-Y2 AS SEEN IN DIRECTION OF ARROWS

Fig. 3A

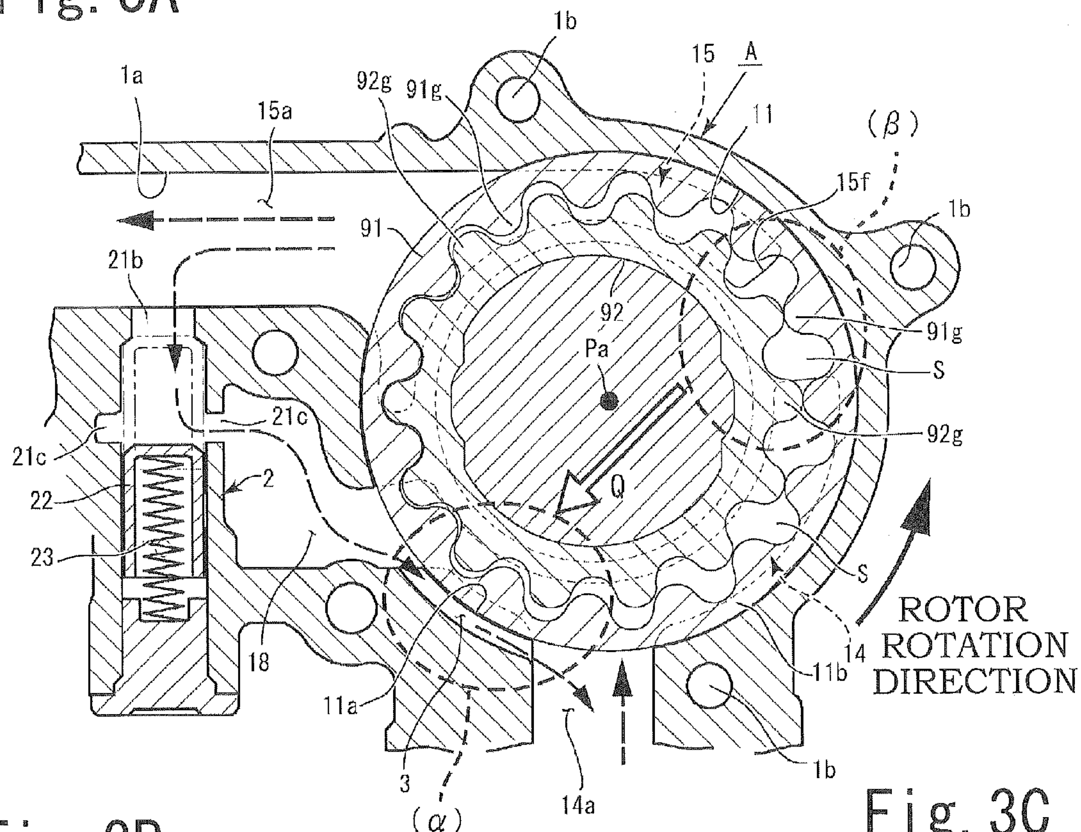
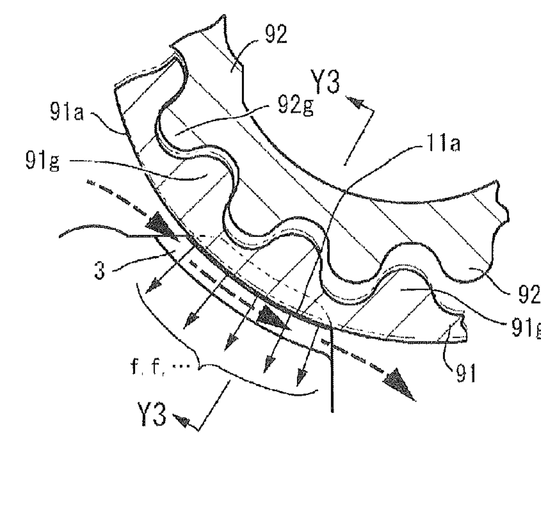


Fig. 3C

Fig. 3B

ENLARGED VIEW OF PART α



ENLARGED VIEW OF PART β

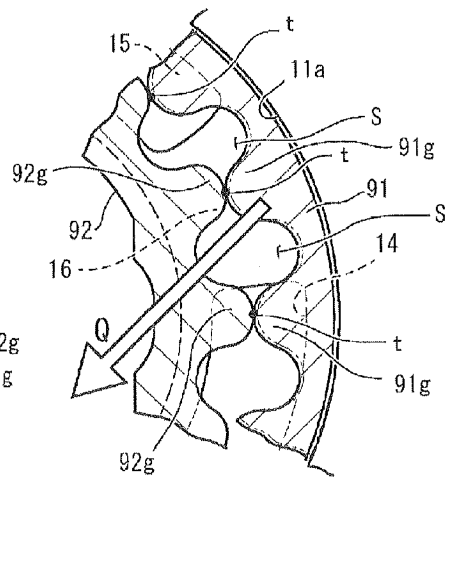


Fig. 4A

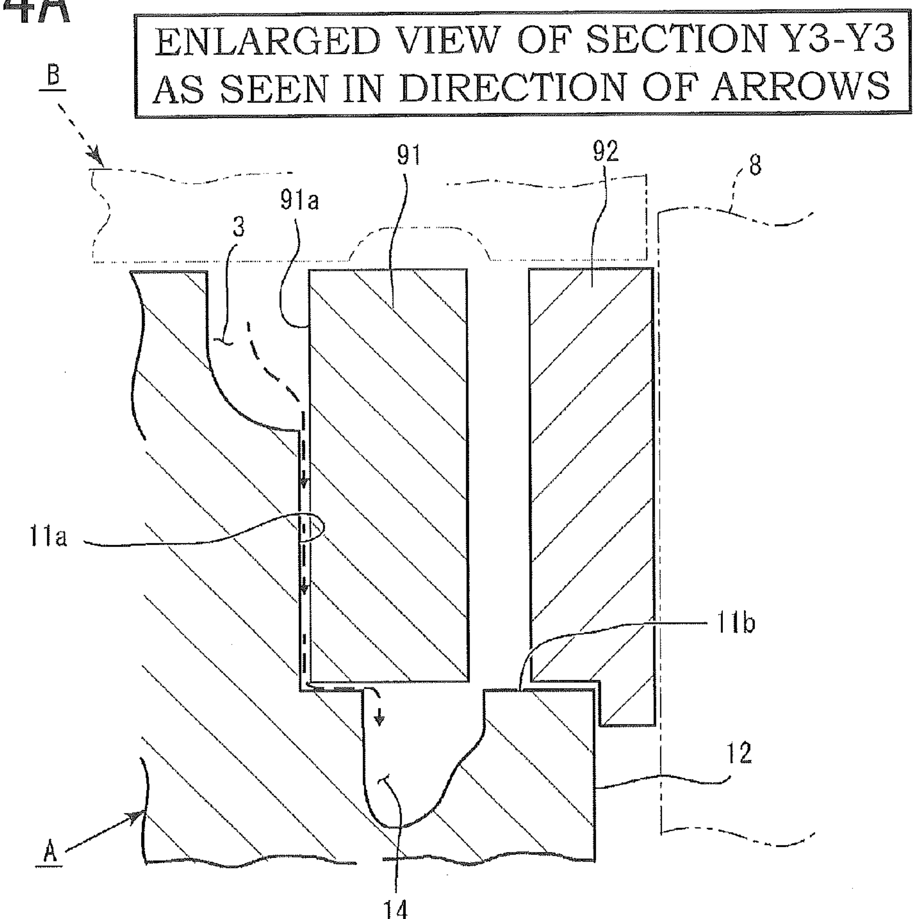
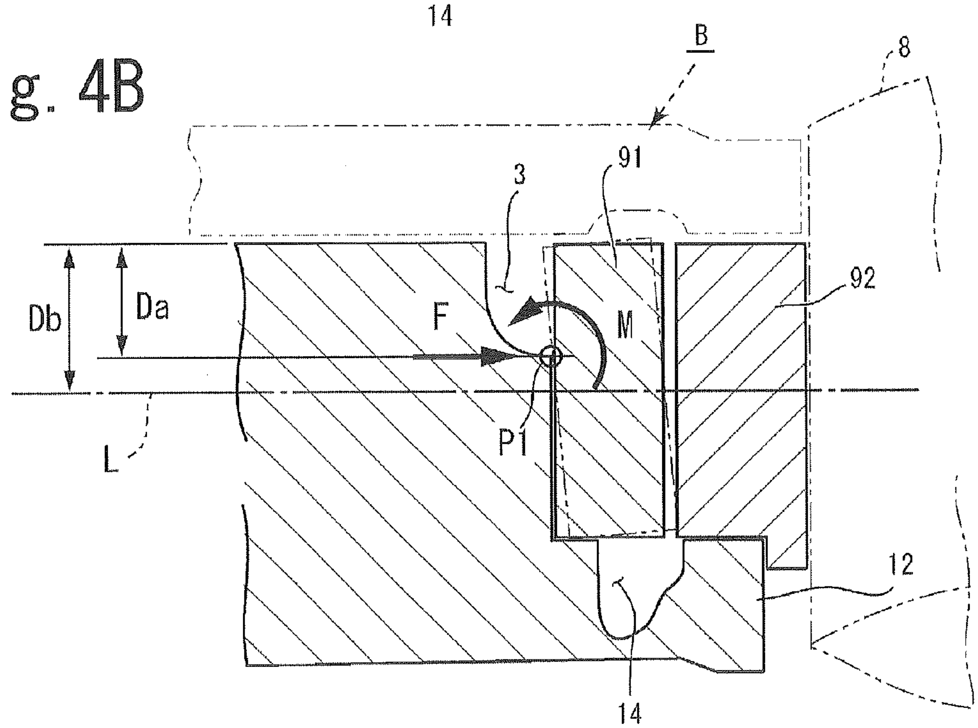

ENLARGED VIEW OF SECTION Y3-Y3
AS SEEN IN DIRECTION OF ARROWS
B
91
92
8
91a
3
11a
11b
12
A
14

Fig. 4B


B
8
91
3
92
Db
Da
F
M
P1
L
12
14

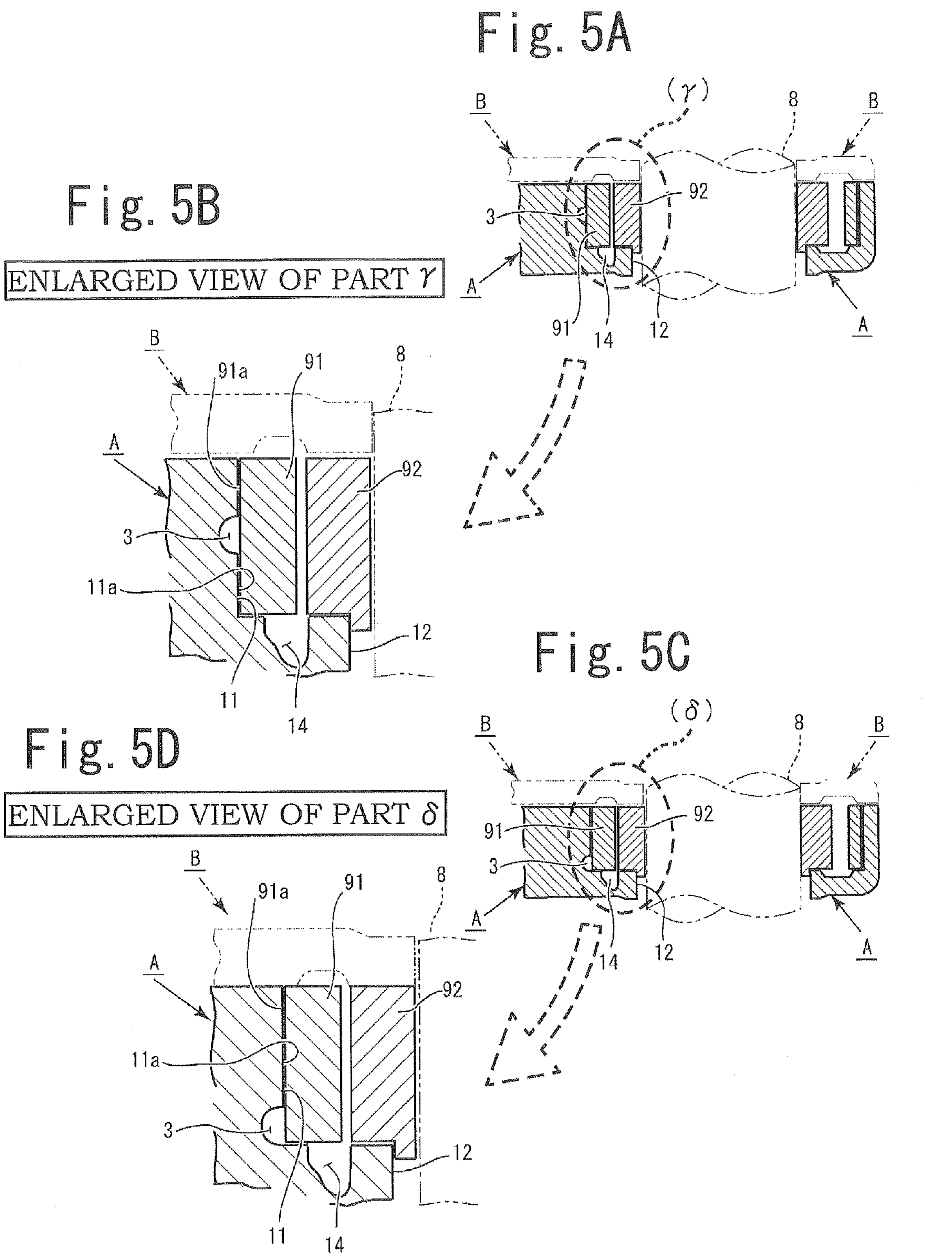


Fig. 5A
(γ)
B
8
B
92
3
A
91
14
12
A
Fig. 5B
ENLARGED VIEW OF PART γ
B
91a
91
8
A
92
3
11a
12
11
14
Fig. 5C
(δ)
B
8
B
91
92
3
A
14
12
A
Fig. 5D
ENLARGED VIEW OF PART δ
B
91a
91
8
A
92
11a
3
12
11
14

Fig. 6A

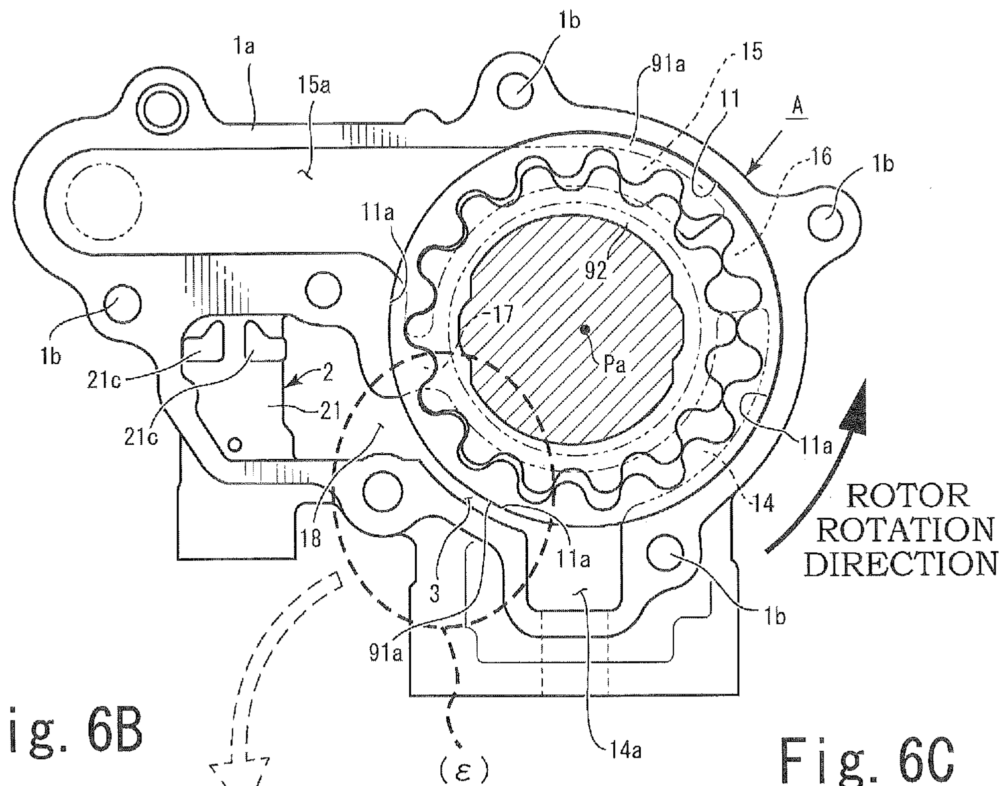


Fig. 6B

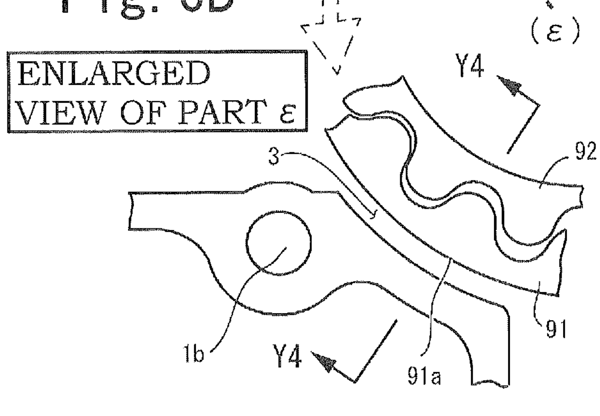


Fig. 6C

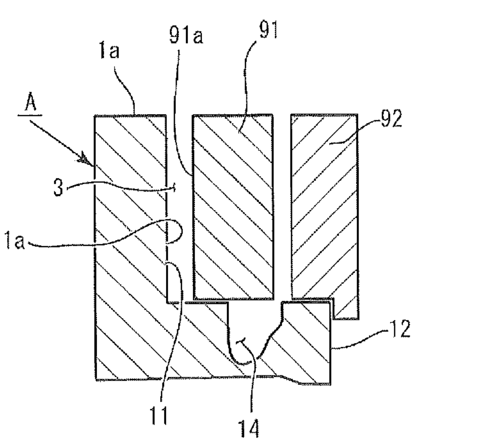


Fig. 7A

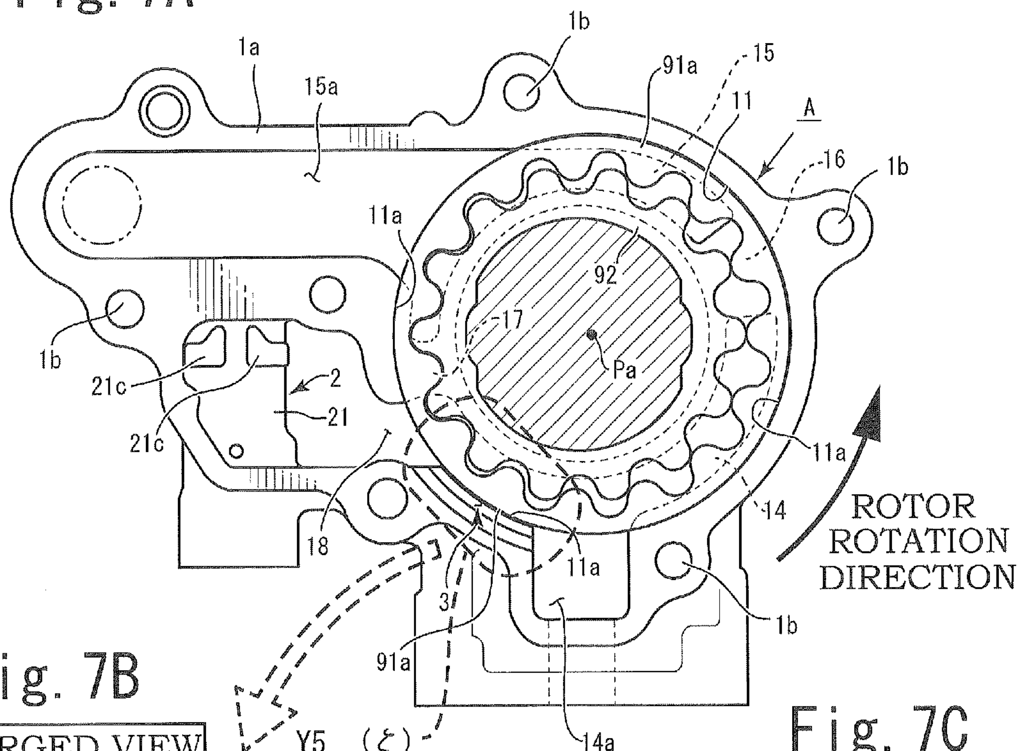


Fig. 7B

ENLARGED VIEW OF PART ζ

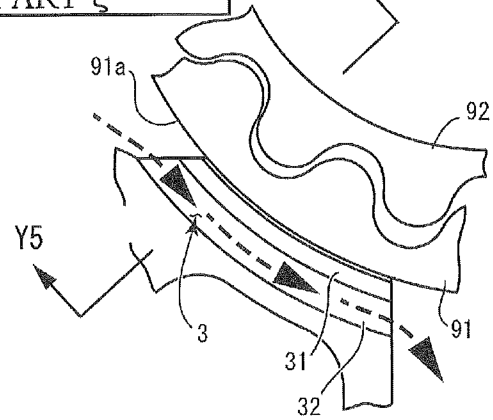
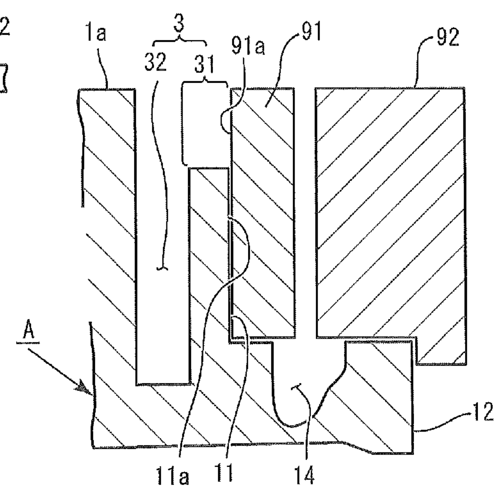


Fig. 7C

SECTION Y5-Y5 AS SEEN IN DIRECTION OF ARROWS



OIL PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a configuration of an oil pump that can achieve a size reduction of the entire pump, reduction in wear of the rotor during operation and that can also achieve longer pump life and reduction in production cost.

2. Description of the Related Art

There are, as conventionally known, internal gear oil pumps with a relief valve. Japanese Patent Application Laid-open No. S63-246482 discloses a specific configuration of such an oil pump. The pump according to Japanese Patent Application Laid-open No. S63-246482 has in general a configuration, in which a circular recess **6** in which inner and outer rotors are arranged has a smooth cover attachment surface **22** therearound to attach a cover **24**, and a plurality of bolt holes **23** drilled at suitable locations for fastening the cover **24**.

An oil return passage **26** is formed in the cover attachment surface **22** in the form of a groove from near a discharge chamber **11** toward an inlet chamber **10**. One end of this oil return passage **26** opens to an inlet passage **12**, while the other end extends as far as to a portion adjacent the discharge chamber **11**. The cover attachment surface **22** is thus divided into a pump chamber-side portion **22***a* that surrounds the circular recess **6**, and an outer portion **22***b*.

A side hole **27***a*, which is drilled in a middle position of a relief passage **27** that opens to an outlet passage **14**, opens to the oil return passage **26**. A known relief valve **28** is mounted in the relief passage **27**, so that lubricating oil under excess pressure is discharged into the oil return passage **26** through the side hole **27***a* to flow back to the inlet chamber **10** when the pressure of discharged oil exceeds a predetermined value.

SUMMARY OF THE INVENTION

According to Japanese Patent Application Laid-open No. S63-246482, the pump chamber-side portion **22***a* is provided between the oil return passage **26** and the circular recess **6** so as to separate the oil return passage **26** and the circular recess **6**. Accordingly, the pump casing **5** is increased in size radially outward by the width of the pump chamber-side portion **22***a*.

The oil return passage **26** is formed independently of and located away from the circular recess **6**. The pump casing **5** has a complex shape because of such a configuration, which causes high production cost. The flow path of the relief oil is long since the oil return passage **26** is formed at a position away from the circular recess **6**, because of which the relief oil may not flow smoothly and it is highly likely that the pressure relief action may not be performed properly.

The technical solutions (objects) of the present invention are to achieve: efficient return of relief oil to the inlet side by a relief valve to ensure a favorable pressure relief action; retardation of wear of the rotor mounted in the pump body to increase pump life; a very compact design; and simple production.

Through vigorous research, the inventors have achieved the above objects by providing an oil pump, which, according to a first aspect of the present invention, includes: a pump body; an outer rotor; and an inner rotor, the pump body including a rotor chamber having an inner circumferential support wall on an inner circumferential side, an inlet port and an outlet port formed in the rotor chamber, an inlet passage communicating with the inlet port, an outlet passage communicating with the outlet port, a relief valve allowing oil to flow from the outlet passage to the inlet passage by relieving pressure, a relief chamber formed on a discharge side of the relief valve, and an oil return passage formed from the relief chamber to the inlet passage; the outer rotor being supported by the inner circumferential support wall of the rotor chamber; and the inner rotor being arranged on an inner side of the outer rotor. The oil return passage is formed in the inner circumferential support wall as a groove-like recess and opens along an outer circumferential surface of the outer rotor.

According to a second aspect of the present invention, in the oil pump according to the first aspect, the oil return passage is formed at and around a symmetric point of a maximum partition part located between a trailing end of the inlet port and a leading end of the outlet port relative to a center point of the rotor chamber, whereby the above objects were achieved. According to a third aspect of the present invention, in the oil pump according to the first aspect, the oil return passage is formed at an upper end portion in a depth direction of the inner circumferential support wall and opened in a surface portion of the rotor chamber, whereby the above objects were achieved. According to a fourth aspect of the present invention, in the oil pump according to the third aspect, the oil return passage is formed to a depth from a surface of the rotor chamber less than half a thickness in an axial direction of the outer rotor, whereby the above objects were achieved.

The above objects were achieved by providing an oil pump, which, according to a fifth aspect of the present invention, includes: a pump body; an outer rotor; and an inner rotor, the pump body including a rotor chamber having an inner circumferential support wall on an inner side, an inlet port and an outlet port formed in the rotor chamber, an inlet passage communicating with the inlet port, an outlet passage communicating with the outlet port, a relief valve allowing oil to flow from the outlet passage to the inlet passage by relieving pressure, a relief chamber formed on a discharge side of the relief valve, and an oil return passage formed from the relief chamber to the inlet passage; the outer rotor being supported by the inner circumferential support wall of the rotor chamber; and the inner rotor being arranged on an inner side of the outer rotor. The oil return passage is formed as a gap extending to a same depth in an axial direction as a depth of the rotor chamber between a body wall portion, located between the relief chamber and the inlet passage, and an outer circumferential surface of the outer rotor.

According to a sixth aspect of the present invention, in the oil pump according to the first aspect, the oil return passage is formed by a gap formed in an upper portion of the inner circumferential support wall and by a deep groove formed on a radially outer side of the inner circumferential support wall in close proximity thereto, so as to communicate the relief chamber with the inlet passage, the deep groove communicating with the gap, whereby the above objects were achieved.

According to the present invention, the oil return passage is formed in the inner circumferential support wall from the relief chamber to the inlet passage as a groove-like recess that opens along an outer circumferential surface of the outer rotor. In this configuration, the outer circumferential surface of the outer rotor forms part of the wall of the oil return passage.

Therefore, the oil return passage of the present invention is not a separate groove-like recess formed at a position away from the rotor chamber of the pump body as seen in conventional pumps, but rather, it forms a groove together with the outer circumferential surface of the outer rotor. Accordingly, the oil pump of the present invention can be made smaller and more lightweight than conventional counterparts.

Moreover, the portion of the inner circumferential support wall of the rotor chamber where the oil return passage is formed does not contact the outer circumferential surface of the outer rotor. Therefore, the area of surface where the rotor chamber and the outer rotor substantially contact each other is reduced, and the smaller contact area leads to lower friction resistance, whereby drive loss is reduced and fuel economy is increased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a partially sectional front view of a first embodiment of the present invention, and FIG. **1**B is a cross-sectional view as seen from the direction of arrows **Y1**-**Y1** in FIG. **1**A;

FIG. **2**A is a partially sectional front view of a pump body in the first embodiment, and FIG. **2**B is a cross-sectional view as seen from the direction of arrows **Y2**-**Y2** in FIG. **2**A;

FIG. **3**A is a longitudinal cross-sectional front view of a pressure relief action in the first embodiment, FIG. **3**B is an enlarged view of part α in FIG. **3**A, and FIG. **3**C is an enlarged view of part β in FIG. **3**A;

FIG. **4**A is an enlarged view as seen from the direction of arrows **Y3**-**Y3** in FIG. **3**B, and FIG. **4**B is an enlarged longitudinal cross-sectional side view of essential parts illustrating how forces act to resist tilting of the outer rotor;

FIG. **5**A is a longitudinal cross-sectional side view of essential parts of a second embodiment of the present invention, FIG. **5**B is an enlarged view of part γ in FIG. **5**A, FIG. **5**C is a longitudinal cross-sectional side view of essential parts of a third embodiment of the present invention, and FIG. **5**D is an enlarged view of part δ in FIG. **5**C;

FIG. **6**A is a partially sectional front view of a fourth embodiment of the present invention, FIG. **6**B is an enlarged view of part ε in FIG. **6**A of the present invention, and FIG. **6**C is a cross-sectional view as seen from the direction of arrows **Y4**-**Y4** in FIG. **6**B; and

FIG. **7**A is a partially sectional front view of a fifth embodiment of the present invention, FIG. **7**B is an enlarged view of part ζ in FIG. **7**A of the present invention, and FIG. **7**C is a cross-sectional view as seen from the direction of arrows **Y6**-**Y6** in FIG. **7**B.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described with reference to the drawings. The oil pump according to the present invention is generally comprised of a pump body A, an outer rotor **91**, and an inner rotor **92** (see FIG. **1**). The pump body A is comprised of a rotor chamber **11**, an inlet port **14**, an outlet port **15**, and a relief valve **2** (see FIG. **2**).

The outer rotor **91** and inner rotor **92** are trochoid or substantially trochoid gears. The outer rotor **91** has a plurality of inner teeth **91***g* formed on the inner periphery, while the inner rotor **92** has a plurality of outer teeth **92***g*. The inner rotor **92** has one fewer number of outer teeth **92***g* than the number of inner teeth **91***g* of the outer rotor **91**, so that there are formed a plurality of interteeth spaces S between the inner teeth **91***g* of the outer rotor **91** and the outer teeth **92***g* of the inner rotor **92**.

The rotor chamber **11** is made up of an inner circumferential support wall **11***a* and a bottom **11***b*. In the present invention, a pump cover B may be provided to the pump body A, and they are both mounted at predetermined locations on an engine housing of a car or the like. The pump body A has a body wall portion **1***a* at the outer periphery. The distal end of the body wall portion **1***a* is formed flat. Suitably spaced bolt holes **1***b* are formed in the body wall portion **1***a* for fixedly attaching the body to the pump cover B with fastening means such as bolts.

A shaft hole **12** is formed in the bottom **11***b* of the rotor chamber **11** for a drive shaft **8** to pass through (see FIG. **1**). Also formed in the bottom **11***b* are the inlet port **14** and the outlet port **15**. Between the trailing end **14***t* of the inlet port **14** and the leading end **15***f* of the outlet port **15** is formed a maximum partition part **16**, while, between the trailing end **15***t* of the outlet port **15** and the leading end **14***f* of the inlet port **14** is formed a minimum partition part **17** (see FIG. **2**).

An inlet passage **14***a* communicates with the inlet port **14**. The inlet passage **14***a* communicates with the outside of the pump body A and allows oil to flow in from a lubrication circuit outside the pump body A. An outlet passage **15***a* communicates with the outlet port **15**. The outlet passage **15***a* allows oil to flow out to the lubrication circuit outside the pump body A.

The inner circumferential support wall **11***a* of the rotor chamber **11** is a portion that holds and rotatably supports the outer rotor **91**. The inner circumferential support wall **11***a* forms a cylindrical inner wall surface, which is non-continuous at portions where it intersects with the inlet port **14** and the outlet port **15** (see FIG. **2**A). Namely, the inner circumferential support wall **11***a* of the rotor chamber **11** is formed from a plurality of wall parts, which hold the outer circumferential surface **91***a* of the outer rotor **91** (see FIG. **3**A).

The relief valve **2** is provided between the inlet port **14** and the outlet port **15**, and serves to return oil from the outlet port **15** side to the inlet port **14** side when the pressure of discharged oil exceeds a predetermined value. A valve member passage **21***a* is formed inside a valve housing **21**, and a relief passage **21***b* is formed at one end in the longitudinal direction of the valve member passage **21***a* to communicate with the outlet passage **15***a*. Part of the oil flowing through the outlet passage **15***a* enters the valve member passage **21***a* through the relief passage **21***b* as relief oil.

A relief drain hole **21***c* is formed in the valve housing **21**, so that the valve member passage **21***a* inside the valve housing **21** communicates with the outside. The relief drain hole **21***c* is opened and closed by a valve member **22** to be described later. The relief drain hole **21***c* is opened to relieve pressure (see FIG. **3**A).

The valve member **22** and a resilient member **23** are arranged inside the valve member passage **21***a* such that the resilient member **23** resiliently presses the valve member **22** to close the relief passage **21***b*. More specifically, a coil spring is used as the resilient member **23**. A relief chamber **18** is formed around a portion where the relief drain hole **21***c* is formed in the valve housing **21** (see FIG. **1**A, FIG. **2**A, FIG. **3**A, and others). The relief chamber **18** is a cavity (space) that communicates the relief drain hole **21***c* with the inlet port **14**. The relief chamber **18** serves to deliver the oil drained from the relief drain hole **21***c* into the inlet port **14**.

Next, an oil return passage **3** in the first embodiment of the present invention will be described. The oil return passage **3** is formed in a suitable region of the inner circumferential support wall **11***a* of the rotor chamber **11**. The oil return passage **3** is formed at a location opposite from the maximum partition part **16**, with the rotation center Pa of the outer rotor **91** being in the middle as a center point, i.e., at a symmetrical point (see FIG. **2**A). This location includes the surrounding region. The oil return passage **3** is formed in the inner circumferential support wall **11***a* between the relief chamber **18** and the inlet passage **14***a*.

The oil return passage **3** is formed as a substantially arcuate recess extending along the circumferential direction of the rotor chamber **11** in a suitable region of the inner circumferential support wall **11***a* (see FIG. **2**). The oil return passage **3** is formed to have a substantially L-shaped cross-sectional shape in a section orthogonal to the circumferential direction from the upper end face to the inner side face of the inner circumferential support wall **11***a*. The corner of the oil return passage **3** with a substantially L-shaped cross-sectional shape may either be rounded or orthogonal.

The inner circumferential support wall **11***a* is shaped like the rest thereof below the oil return passage **3** in the depth direction so as to support the outer circumferential surface **91***a* of the outer rotor **91** housed in the rotor chamber **11** (see FIG. **1**B and FIG. **2**B). Therefore, the outer rotor **91** is prevented from moving in radial directions by parts of the inner circumferential support wall **11***a* supporting the outer circumferential surface **91***a* of the outer rotor **91**. As radial rocking movement of the outer rotor **91** is reduced, knocking noise produced by the outer rotor **91** colliding the rotor chamber **11**, or damage to the outer rotor **91**, can be reduced.

Part of the outer circumferential surface **91***a* of the outer rotor **91** that passes the region of the oil return passage **3** forms the substantially groove-like recess together with the oil return passage **3**. The oil return passage **3** is a fluid passage that communicates the relief chamber **18** with the inlet passage **14***a* and allows the relief oil to return from the relief chamber **18** back to the inlet passage **14***a* through the oil return passage **3** (see FIG. **2**A).

The relief oil flowing through the oil return passage **3** thus makes direct contact with the outer circumferential surface **91***a* of the outer rotor **91**, so that, as the outer rotor **91** rotates inside the rotor chamber **11**, oil can be distributed between the outer circumferential surface **91***a* of the outer rotor **91** and the inner circumferential support wall **11***a* (see FIG. **3**A and FIG. **3**B).

Since the oil return passage **3** is formed along the outer circumferential surface **91***a* of the outer rotor **91**, the pump body A can be made smaller as compared to the conventional pump that has the oil passage at a position away from the rotor chamber **11**. The contact area between the inner circumferential support wall **11***a* and the outer circumferential surface **91***a* of the outer rotor **91** is reduced in the region where the oil return passage **3** is formed (see FIG. **1**B), so that the friction resistance between the outer rotor **91** and the rotor chamber **11** is reduced. Drive loss is accordingly reduced, and fuel economy is improved.

Moreover, since the oil return passage **3** is located on the opposite side from the maximum partition part **16** between the trailing end **14***t* of the inlet port **14** and the leading end **15***f* of the outlet port **15**, with the rotation center Pa of the outer rotor **91** being in the middle (at the symmetric point), oil that flows from the relief chamber **18** back to the inlet passage **14***a* passes through the oil return passage **3** (see FIG. **3**).

Since the pressure of oil flowing through the oil return passage **3** is negative, the outer rotor **91** is pulled from the side of the maximum partition part **16** toward the oil return passage **3** by the force of negative pressure f (see FIG. **3**B). The direction in which the outer rotor **91** is pulled by the force of negative pressure f is indicated by arrow Q in FIG. **3**A and FIG. **3**C.

Therefore, the tip clearance t between the inner teeth of the outer rotor **91** and the outer teeth of the inner rotor **92** on the maximum partition part **16** (see FIG. **3**C) is reduced. That is, the seal tightness of the interteeth spaces S between the outer rotor **91** and the inner rotor **92** on the maximum partition part **16** is increased, so that leakage from the outlet side to the inlet side is reduced, and the volume efficiency (ratio of actual discharge to theoretical discharge) can be increased.

Moreover, the oil flowing through the oil return passage **3** can be delivered to the gap between the inner circumferential support wall **11***a* of the rotor chamber **11** and the outer circumferential surface **91***a* of the outer rotor **91** and serves as lubricating oil to allow smooth rotation of the outer rotor **91** (see FIG. **4**A).

Next, the relationship between the depth of the oil return passage **3** and the length in the thickness direction of the outer rotor **91** will be explained. One half the length in the depth direction of the rotor chamber **11** is denoted as Db, while the length in the depth direction of the oil return passage **3** is denoted as Da (see FIG. **4**B). The imaginary line L in the drawing indicates the centerline in the thickness direction of the outer rotor. The depth direction of the rotor chamber **11** and the thickness direction of the outer rotor **91** are the same. The depth Da of the oil return passage **3** is set smaller than half the length in the depth direction Db of the rotor chamber **11**. Namely, Db>Da.

Therefore, in the region where the oil return passage **3** is formed, the inner circumferential support wall **11***a* extends from the bottom **11***b* of the rotor chamber **11** in the height direction to a point beyond half the depth of the rotor chamber **11**. Accordingly, even if there is created a rotational force M that causes the outer rotor **91** to swing and tilt relative to the rotor chamber **11** around the contact point P**1** between the lower end in the depth direction of the oil return passage **3** and the outer circumferential surface **91***a* of the outer rotor **91**, the outer circumferential surface **91***a* of the outer rotor **91** is supported by part of the inner circumferential support wall **11***a* up to a point higher than half the thickness of the outer rotor.

That is, the outer rotor **91** is supported by the inner circumferential support wall **11***a* over a range that extends beyond the center of gravity in the axial direction of the outer circumferential surface **91***a* (midpoint of the thickness of the outer rotor **91**). Therefore, the reaction force F from the contact point P**1** against the outer rotor **91** abutting the contact point P**1** acts on a point higher than the midpoint of the thickness of the outer rotor **91** (see FIG. **4**B). This configuration makes it difficult for the outer rotor **91** to tilt inside the rotor chamber **11** and thus the outer rotor **91** is prevented from abutting the inner circumferential support wall **11***a* obliquely, and possible damage to the outer rotor **91** is reduced.

In a second embodiment of the present invention, the oil return passage **3** is formed substantially at a midpoint in the depth direction of the inner circumferential support wall **11***a* of the rotor chamber **11** (see FIG. **5**A and FIG. **5**B). In this embodiment, the outer circumferential surface **91***a* of the outer rotor **91** passing the oil return passage **3** is supported stably by both upper and lower portions of the inner circumferential support wall **11***a* on both sides of the oil return passage **3**.

In a third embodiment of the present invention, the oil return passage **3** is formed at the lowermost position in the depth direction of the inner circumferential support wall **11***a* of the rotor chamber **11** (see FIG. **5**C and FIG. **5**D). In the third embodiment, as the oil return passage **3** is formed at the lowermost position in the depth direction, i.e., at the lower end of the inner circumferential support wall **11***a* and surrounded by the bottom **11***a* of the rotor chamber **11** and the outer circumferential surface **91***a* of the outer rotor **91**, it is substantially tubular so that it can deliver relief oil from the relief chamber to the inlet port most stably.

In a fourth embodiment of the present invention, the oil return passage **3** is not formed in the inner circumferential support wall **11***a* of the rotor chamber **11** but on the inner side of the body wall portion **1***a* (see FIG. **6**). In this embodiment, the oil return passage **3** extends axially all along the outer circumferential surface **91***a* of the outer rotor **91**.

Therefore, in this embodiment, the outer circumferential surface **91***a* of the outer rotor **91** passing the region where the oil return passage **3** is formed does not make contact with the inner circumferential support wall **11***a*. The oil return passage **3** has a large volume so that it can deliver a large amount of relief oil from the relief chamber **18** to the inlet passage **14***a*.

Next, an oil return passage **3** in a fifth embodiment of the present invention will be described. The oil return passage **3** of the fifth embodiment is substantially an embodiment of a narrower concept of the first embodiment described in the foregoing. The oil return passage **3** of the first embodiment is formed as a groove-like recess in the inner circumferential support wall **11***a* and opens along the outer circumferential surface **91***a* of the outer rotor **91**. In contrast, the oil return passage **3** of the fifth embodiment is made up of two parts, a gap **31** and a deep groove **32**. The gap **31** and the deep groove **32** both extend between the relief chamber **18** and the inlet passage **14***a* and communicate with each other.

The gap **31** is formed by cutting away an upper portion of the inner circumferential support wall **11***a* along the circumferential direction of the wall **11***a* (see FIG. **7**C). In other words, the upper end of the inner circumferential support wall **11***a* is lower in the region where the oil return passage **3** is formed than other portions of the inner circumferential support wall **11***a*. The top of the inner circumferential support wall **11***a* where the gap **31** is formed is flat, and the height is constant. The gap **31** formed above the inner circumferential support wall **11***a* opens along the outer circumferential surface **91***a* of the outer rotor **91** (see FIG. **7**C).

The deep groove **32** is formed on a radially outer side of the inner circumferential support wall **11***a* in close proximity thereto (see FIG. **7**B and FIG. **7**C). The deep groove **32** is a fluid passage that is arcuate similarly to the inner circumferential support wall **11***a*. The deep groove **32** is formed in communication with and between the relief chamber **18** and the inlet passage **14***a* as mentioned above, the upper part of the deep groove **32** communicating with the gap **31**.

The deep groove **32** has a rectangular cross-sectional shape, and its bottom may be deeper, or shallower than, or equal to the bottom of the rotor chamber **11**. The deep groove **32** should preferably be located closest possible to the inner circumferential support wall **11***a*. The oil return passage **3** formed by such deep groove **32** and gap **31** has a substantially inverted L-shaped cross-sectional shape in a section orthogonal to the circumferential direction of the inner circumferential support wall **11***a* (see FIG. **7**C).

Part of the inner circumferential support wall **11***a* stands as an upright wall portion beside the deep groove **32**. In the fifth embodiment, in this way, the gap **31** that forms part of the oil return passage **3** extends along the circumferential direction of the inner circumferential support wall **11***a*, so that the oil return passage **3** is open along the outer circumferential surface **91***a* of the outer rotor **91** through the gap **31** (see FIG. **7**A and FIG. **7**B).

According to the fifth embodiment, the oil return passage **3** formed by the gap **31** and the deep groove **32** can return a large amount of relief oil from the relief chamber **18** to the inlet passage **14***a*, so that the pressure relief action can be performed most favorably. The gap **31** allows part of the oil being returned to be distributed between the inner circumferential support wall **11***a* below the gap **31** and the outer circumferential surface **91***a* of the outer rotor **91**, so that the outer rotor **91** can rotate very smoothly.

Similarly to the first to fourth embodiments, the oil return passage **3** in the fifth embodiment should preferably be formed at or around a location opposite from the maximum partition part **16**, with the rotation center Pa of the outer rotor **91** being in the middle as a center point, i.e., at a symmetric point.

According to the second aspect of the invention, the oil return passage is located opposite from the maximum partition part between the trailing end of the inlet port and the leading end of the outlet port, with the rotation center of the outer rotor being in the middle. Namely, the oil return passage is located at or around a symmetric point of the maximum partition part relative to the rotation center of the outer rotor as the point of symmetry.

Relief oil flowing back from the relief chamber to the inlet passage flows through the oil return passage formed at such a position. Since a negative pressure is created by the relief oil flowing through the oil return passage, the outer rotor is pulled from the maximum partition part toward the oil return passage.

The tip clearance between the inner rotor and the outer rotor is reduced on the maximum partition part, or both rotors almost abut each other, so that airtight interteeth spaces are formed between the outer rotor and the inner rotor. Leakage to the inlet side is thus reduced, and the volume efficiency (actual discharge to theoretical discharge) can be improved.

According to the third aspect of the invention, the oil return passage is formed at an upper end portion in the depth direction of the inner circumferential support wall and opened to a surface portion of the rotor chamber. It is therefore provided as a recess in the thickness direction of the outer rotor, with a support portion that partially supports the outer circumference of the outer rotor. That is, the inner circumferential support wall exists in the region of the rotor chamber where the oil return passage is formed.

Since the outer circumferential surface of the outer rotor is supported by the remaining inner circumferential support wall in the region where the oil return passage is formed, the outer rotor is prevented from moving in radial directions. As radial rocking movement of the outer rotor is reduced, knocking noise produced by the outer rotor colliding the pump body or inner circumferential support wall, or damage to the outer rotor, can be reduced.

Since the oil return passage is formed at the upper end portion in the depth direction of the inner circumferential support wall and opened to a surface portion of the rotor chamber, it can be formed by casting in which the casting with holes is removed from the mold, i.e., there is no need of post-processing such as machining or welding but the groove can be formed from the beginning by casting, so that the production cost can be reduced. Other effects of the present invention as described herein are likewise achieved.

According to the fourth aspect of the invention, the oil return passage is formed to a depth from the surface of the rotor chamber less than half the thickness in the axial direction of the outer rotor. That is, the outer rotor is supported by the inner circumferential support wall at the center of gravity in the axial direction of the outer circumferential surface (midpoint of the thickness of the outer rotor), so that it is difficult for the outer rotor to tilt, and thus the outer rotor is prevented from tilting and abutting the inner circumferential support wall of the oil pump body obliquely, and possible damage to the outer rotor is reduced.

According to the fifth aspect of the invention, the oil return passage is formed as a gap between a body wall portion located between the relief chamber and the inlet passage and the outer circumferential surface of the outer rotor. As there is no inner circumferential support wall in the region where the oil return passage is formed in the rotor chamber, the outer circumferential surface of the outer rotor does not contact the inner circumferential support wall there, so that friction resistance is reduced, whereby drive loss is reduced and fuel economy is improved. The oil return passage has a large volume so that it can deliver a large amount of relief oil from the relief chamber to the inlet passage and ensure a favorable pressure relief action. Moreover, the shape of the pump body is made simple, so that molds for casting the pump body can be made simple.

According to the sixth aspect of the invention, the oil return passage is formed as a gap formed in an upper portion of the inner circumferential support wall and a deep groove formed on the radially outer side of the inner circumferential support wall in close proximity thereto, such as to communicate the relief chamber with the inlet passage. The deep groove communicates with the gap so that the gap and the deep groove together can return a large amount of relief oil from the relief chamber to the inlet passage, whereby the pressure relief action can be performed most favorably. The gap allows part of the oil being returned to be distributed between the inner circumferential support wall below the gap and the outer circumferential surface of the outer rotor, so that the outer rotor can rotate very smoothly.

What is claimed is:

1. An oil pump, comprising:

a pump body;

an outer rotor; and

an inner rotor,

the pump body including a rotor chamber having an inner circumferential support wall on an inner circumferential side, an inlet port and an outlet port formed in the rotor chamber, an inlet passage communicating with said inlet port, an outlet passage communicating with said outlet port, a relief valve allowing oil to flow from the outlet passage to said inlet passage by relieving pressure, a relief chamber formed on a discharge side of the relief valve, and an oil return passage formed from said relief chamber to said inlet passage;

the outer rotor being supported by the inner circumferential support wall of said rotor chamber; and

the inner rotor being arranged on an inner circumferential side of the outer rotor,

wherein said oil return passage is formed in said inner circumferential support wall as a groove-like recess and opens along an outer circumferential surface of said outer rotor.

2. The oil pump according to claim **1**, wherein said oil return passage is formed at and around a symmetric point of a maximum partition part located between a trailing end of said inlet port and a leading end of said outlet port relative to a center point of said rotor chamber.

3. The oil pump according to claim **1**, wherein said oil return passage is formed at an upper end portion in a depth direction of said inner circumferential support wall and opened in a surface portion of said rotor chamber.

4. The oil pump according to claim **3**, wherein said oil return passage is formed to a depth from a surface of the rotor chamber less than half a thickness in an axial direction of said outer rotor.

5. The oil pump according to claim **1**, wherein said oil return passage is formed by a gap formed in an upper portion of said inner circumferential support wall and by a deep groove formed on a radially outer side of said inner circumferential support wall in close proximity thereto, so as to communicate said relief chamber with said inlet passage, the deep groove communicating with said gap.

6. The oil pump according to claim **1**, wherein said oil return passage is formed by a gap in said inner circumferential support wall and by a deep groove in said inner circumferential support wall in close proximity thereto, so as to communicate said relief chamber with said inlet passage, the deep groove communicating with said gap.

7. The oil pump according to claim **1**, wherein the oil return passage forms a groove together with the outer circumferential surface of the outer rotor.

8. An oil pump, comprising:

a pump body;

an outer rotor; and

an inner rotor,

the pump body including a rotor chamber having an inner circumferential support wall on an inner circumferential side, an inlet port and an outlet port formed in the rotor chamber, an inlet passage communicating with said inlet port, an outlet passage communicating with said outlet port, a relief valve allowing oil to flow from the outlet passage to said inlet passage by relieving pressure, a relief chamber formed on a discharge side of the relief valve, and an oil return passage formed from said relief chamber to said inlet passage;

the outer rotor being supported by the inner circumferential support wall of said rotor chamber; and

the inner rotor being arranged on an inner circumferential side of the outer rotor, wherein

said oil return passage is formed as a gap extending to a same depth in an axial direction as a depth of said rotor chamber between a body wall portion, located between said relief chamber and said inlet passage, and an outer circumferential surface of said outer rotor.

9. The oil pump according to claim **8**, wherein said oil return passage is formed by a gap in an upper portion of said inner circumferential support wall and by a deep groove on a radially outer side of said inner circumferential support wall in close proximity thereto, so as to communicate said relief chamber with said inlet passage, the deep groove communicating with said gap.

10. The oil pump according to claim **8**, wherein said oil return passage is formed by a gap formed in said inner circumferential support wall and by a deep groove formed in said inner circumferential support wall in close proximity thereto, so as to communicate said relief chamber with said inlet passage, the deep groove communicating with said gap.

11. The oil pump according to claim **8**, wherein the oil return passage forms a groove together with the outer circumferential surface of the outer rotor.

* * * * *